

Structural Steel High-Strength Bolt Installation and Inspection Procedures

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McMurdo, Palmer, and South Pole Stations

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Active Divisions/Departments

FEMC

Raytheon Polar Services Company

Facilities, Engineering, Maintenance, and Construction (FEMC)

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Table of Contents

Table of Contents	i
Purpose.....	1
Responsibility	1
Construction Coordinator, FEMC	1
Quality Assurance Inspector.....	1
Discussion	1
Requirements	2
Quality Assurance Equipment	2
Tools	2
Other Equipment.....	2
Tightening method for Snug-Tightened Joints	2
Inspection of Snug-Tightened Joints.....	3
Turn-of-Nut Pretensioning.....	3
Inspection for Turn-of-Nut Pretensioning.....	4
Calibrated Wrench Pretensioning	4
Direct- Tension-Indicator for Pretensioning	6
Inspection for Direct-Tension-Indicator Pretensioning	7
Tension-Control Bolt Pretensioning (Twist-Off-Type).....	7
Procedure for Handling and Storage of Fasteners	8
References.....	9
Records	9
Attachments	9

Table 8.1. Minimum Bolt Pretension for Pretensioned and Slip-Critical Joints

Table 8.2. Nut Rotation from Snug Tight Condition for Turn-of-Nut
 Pretensioning^{a,b}

Purpose

This procedure outlines five different methods for the proper tightening of high-strength bolts and testing of bolt tension at McMurdo, Palmer, and the South Pole Stations.

Responsibility

Construction Coordinator, FEMC

Assigns Quality Assurance Inspector

Quality Assurance Inspector

Quality Assurance Inspector, who is assigned by the Construction Coordinator.

Discussion

The American Institute of Steel Construction (AISC) requires adherence to certain procedures for tightening high-strength bolts. Proper high-strength bolt installation includes periodic quality assurance by tightening the bolts in a device capable of indicating bolt tension. All quality assurance inspections must be conducted by someone other than the personnel directly involved with installation.

Requirements

Quality Assurance Equipment

Spud wrench, calibrated torque wrench, feeler gauge.

Tools

Impact wrench, Skidmore bolt tension calibrator, Tone shear wrench w/dual concentric sockets, gloves, hard hats, ladder (if above eye level), and safety glasses.

Other Equipment

Hardened washers, nuts, and bolts.

Tightening method for Snug-Tightened Joints

All boltholes shall be aligned to permit insertion of the bolts without undue damage to the threads. Bolts shall be placed in all holes with washers positioned as required in Section 6.1, page 40 of the *Specification for Structural Joints Using ASTM A325 or A490 Bolts*, June 23, 2001 specification book and nuts threaded to complete the assembly. Compacting the *joint* to the snug-tight condition shall progress systematically from the most rigid part of the *joint*. The snug-tightened condition is the tightness that is attained with a few impacts of an impact wrench or the full effort of a worker using an ordinary spud wrench to bring the connected plies into *firm contact*. For additional information see the highlighted Commentary portion under Section 8.1, page 46 of *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.

Inspection of Snug-Tightened Joints

Prior to the *start of work*, it shall be ensured that all fastener components to be used in the work meet the requirements in Section 2 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*). Subsequently, it shall be ensured that all connected plies meet the requirements in Sections 3.3 and 3.4 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*). After the *connections* have been assembled, it shall be visually ensured that the plies of the connected elements have been brought into *firm contact* and that washers have been used as required in Section 6 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*). No further evidence of conformity is required for *snug-tightened joints*. The magnitude of the clamping force that exists in a *snug-tightened joint* is not a consideration.

Inspection requirements for snug-tightened joints consist of the following:

- Verification that the proper fastener components were used
- The connected elements were fabricated properly, and
- The bolted joint was drawn into firm contact

Because pretension is not required for the proper performance of a *snug-tightened joint*, the installed bolts should not be inspected to determine the actual installed pretension.

Turn-of-Nut Pretensioning

All bolts shall be installed in accordance with the requirements in Section 8.1 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*), with washers positioned as required in Section 6.2 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*). Subsequently, the nut or head rotation specified in Table 8.2 (See page 10 of this procedure) shall be applied to all *fastener assemblies* in the *joint*, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts. The part not turned by the wrench shall be prevented from rotating during this operation. For additional information see

the highlighted Commentary portion under Section 8.2.1, page 48 of *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.

Inspection for Turn-of-Nut Pretensioning

The *inspector* shall observe the pre-installation verification testing required in Section 8.2.1 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*). Subsequently, it shall be ensured by *routine observation* that the bolting crew properly rotates the turned element relative to the unturned element by the amount specified in Table 8.2. Alternatively, when *fastener assemblies* are match-marked after the initial fit-up of the *joint* but prior to pretensioning, visual inspection after pretensioning is permitted in lieu of routine observation. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 (See page 10 of this procedure) shall not cause rejection. For additional information see the highlighted Commentary portion under Section 9.2.1, page 54 of *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.

Calibrated Wrench Pretensioning

The pre-installation verification procedures specified in Section 7 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*) shall be performed daily for the calibration of the installation wrench. **Torque values determined from tables or from equations that claim to relate torque to pretension without verification shall not be used.**

All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. Subsequently, the installation torque determined in the pre-installation verification of the *fastener assembly* (Section 7) shall be applied to all bolts in the *joint*, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts. The part not

turned by the wrench shall be prevented from rotating during this operation. Application of the installation torque need not produce a relative rotation between the bolt and nut that is greater than the rotation specified in Table 8.2

The scatter in installed pretension can be significant when torque-controlled methods of installation are used. The variables that affect the relationship between torque and pretension include:

- The finish and tolerance on the bolt and nut threads
- The uniformity, degree and condition of lubrication
- The shop or job-site conditions (dust, dirt, or corrosion on the threads)
- The friction between the turned element and the supporting surface
- The variability of the air supply (length of air lines, and number of wrenches working from the same source)
- The condition, lubrication, and power supply for the torque wrench
- The repeatability of the performance of any wrench that senses or responds to the level of the applied torque

For calibrated wrench pretensioning, **wrenches must be calibrated:**

1. Daily
2. When the *lot* of any component of the fastener assembly is changed
3. When the *lot* of any component of the fastener assembly is re-lubricated
4. When significant differences are noted in the surface condition of the bolt threads, nuts or washers, or
5. When any major component of the wrench including lubrication, hose and air supply are altered.

It is also important that:

- The fastener components are protected from dirt and moisture at the job-site or shop as required in Section 2 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*)
- Washers are used as specified in Section 6, and

- The time between removal from protected storage and wrench calibration and final positioning is minimized.

Results Inspection for Calibrated Wrench Pretensioning

The *inspector* shall observe the pre-installation verification testing required in Section 8.2.2 (*Specification for Structural Joints Using ASTM A325 or A490 Bolts*). Subsequently, it shall be ensured by routine observation that the bolting crew properly applies the calibrated wrench to the turned element. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection.

For proper inspection of the method, it is necessary for the *inspector* to observe the required pre-installation verification testing of the *fastener assemblies* and the method to be used, followed by monitoring of the work in progress to ensure that the method is routinely and properly applied within the limits on time between removal of protected storage and final positioning.

Direct- Tension-Indicator for Pretensioning

Direct tension indicators that meet the requirements of ASTM F959 shall be used. The pre-installation verification procedures specified in Section 7 shall demonstrate that, when the pretension in the bolt reaches 1.05 times that specified for installation and inspection in Table 8.1, the gap is not less than the job inspection gap in accordance with ASTM F959.

All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. The installer shall verify that the direct-tension- indicator protrusions have not been compressed to a gap that is less than the job inspection gap during this operation, and if this has occurred, the direct tension indicator shall be removed and replaced. Subsequently, all bolts in the *joint* shall be pretensioned, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts. The installer shall verify that the direct tension indicator protrusions have been compressed to a gap

that is less than the job inspection gap. (See Figure. C-8.1. Proper use and orientation of ASTM F959 direct-tension-indicator page 52 of *Specification for Structural Joints Using ASTM A325 or A490 Bolts*). For additional information see the highlighted Commentary portion under Section 8.2.4, page 51 of *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.

Inspection for Direct-Tension-Indicator Pretensioning

The *inspector* shall observe the pre-installation verification testing required in Section 8.2.4. Subsequently, but prior to pretensioning, it shall be ensured by *routine observation* that the appropriate feeler gage is accepted in at least half of the spaces between the protrusions of the direct tension indicator and that the protrusions are properly oriented away from the work. If the appropriate feeler gage is accepted in fewer than half of the spaces, the direct tension indicator shall be removed and replaced. After pretensioning, it shall be ensured by *routine observation* that the appropriate feeler gage is refused entry into at least half of the spaces between the protrusions. No further evidence of conformity is required. A pretension that is greater than that specified in Table 8.1 shall not be cause for rejection.

Tension-Control Bolt Pretensioning (Twist-Off-Type)

Twist-Off-Type tension-control bolt assemblies that meet the requirements of ASTM F1852 shall be used.

All *fastener assemblies* shall be installed in accordance with the requirements in Section 8.1 without severing the splined end and with washers positioned as required in Section 6.2. If a splined end is severed during this operation, the fastener assembly shall be removed and replaced. Subsequently, all bolts in the *joint* shall be pretensioned with the twist-off-type tension-control bolt

installation wrench, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts. For additional information see the highlighted Commentary portion under Section 8.2.3, page 50 of *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.

Results Inspection for Twist-Off-Type Tension-Control Bolt Pretensioning

The *inspector* shall observe the pre-installation verification testing required in Section 8.2.3. Subsequently, it shall be ensured by *routine observation* that the splined ends are properly severed during installation by the bolting crew. No further evidence of conformity is required. A pretension that is greater than that specified in Table 8.1 shall not be cause for rejection.

Procedure for Handling and Storage of Fasteners

To properly handle and store bolts, nuts and washers, the following steps shall be followed:

1. Ensure that all fasteners (bolts, nuts, and washers) are properly identified and labeled.
2. Handle fasteners in such a way that they are not damaged, soiled, corroded or stripped of their lubricant.
3. Protect fasteners from dirt and moisture on the job site. Do not clean manufacturer's lubricant from fasteners, and note any hazards listed on MSDS for the lubricant.
4. Store fasteners in a clean, dry place in such a fashion that they are not in danger of damage or intermixing.
5. Prior to using, conduct a visual inspection of all fasteners to verify that they are of the correct type, size, and length for the intended use, and they are not damaged, soiled, corroded, or stripped of their lubricant.

Note Only remove as many fasteners that are anticipated to be installed and tightened during a work shift from protected storage. Return unused fasteners to protected storage at the end of the shift.

6. Fasteners for slip critical connections, which must be cleaned of accumulated rust or dirt resulting from job site conditions, shall be cleaned and re-lubricated prior to installation.

References

AISC ASD 9TH Edition

Specification for Structural Joints Using ASTM A325 or A490 Bolts, June 23, 2000

Records

There are no records generated with this procedure.

Attachments

Table 8.1. Minimum Bolt Pretension for Pretensioned and Slip-Critical Joints

Table 8.2. Nut Rotation from Snug Tight Condition for Turn-of-Nut Pretensioning^{a,b}

(Attachments Courtesy of *Specification for Structural Joints Using ASTM A325 or A490 Bolts, June 23, 2000*)

Table 8.1. Minimum Bolt Pretension for Pretensioned and Slip-Critical Joints

Nominal Bolt Diameter d_{b3} in.	Specified Minimum Bolt Pretension T_{m3} kips ^a	
	A325 Bolts	A490 Bolts
$\frac{1}{2}$	12	15
$\frac{5}{8}$	19	24
$\frac{3}{4}$	28	35
$\frac{7}{8}$	39	49
1	51	64
1 $\frac{1}{8}$	56	80
1 $\frac{1}{4}$	71	102
1 $\frac{3}{8}$	85	121
1 $\frac{1}{2}$	103	148

^a Equal to 70 percent of specified minimum tensile strengths of bolts as specified in ASTM Specifications for tests of full size ASTM A325 and A490 bolts with UNC threads loaded in axial tension, rounded to the nearest kip.

For additional information see the highlighted Commentary portion under Section 8.2, page 47 of *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.

Table 8.2. Nut Rotation from Snug Tight Condition for Turn-of-Nut Pretensioning^{a,b}

Bolt length ^c	Disposition of Outer Face of Bolted Parts		
	Both faces normal to bolt axis	One face normal to bolt axis and other sloped not more than 1:20 ^d	Both faces sloped not more than 1:20 from normal to bolt axis ^d
Not more than $4d_b$	1/3 turn	1/2 turn	2/3 turn
More than $4d_b$ but not more than $8d_b$	1/2 turn	2/3 turn	5/6 turn
More than $8d_b$ but not more than $12d_b$	2/3 turn	5/6 turn	1 turn

^a Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For required nut rotations of 1/2 turn and less, the tolerance should be plus or minus 30 degrees; for required nut rotations of 2/3 turn and more, the tolerance is plus or minus 45 degrees.

^b Applicable only to joints in which all material within the grip is steel.

^c When the bolt length exceeds $12d_b$, the required nut rotation shall be determined by actual testing in a suitable tension calibrator that simulates the conditions of solidly fitting steel.

^d Beveled washer not used.

For additional information see the highlighted Commentary portion under Section 8.2.1, page 48 of *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.